THE BRAIN OF THE EMBRYO SOFT-SHELLED TURTLE.

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In a paper read before the Microscopical Society last year, upon the "Comparative Morphology of the Brain of the Soft-shelled Turtle (*Amyda mutica*) and the English Sparrow (*Passer domesticus**)," certain questions were raised, which could only be answered by studying the development in the soft-shelled turtle, as: When and how do the characteristic features of the brain in this group of turtles arise? When and how do those features arise which distinguish them from birds?

Professor Eigenmann, who was present, kindly sent me six embryos of *Aspidinectes*, a closely allied genus of the turtle, in different stages of development. Serial sections were made of the heads and mesal views reconstructed. A brief summary of the result obtained is given below. Fuller statement, with illustration, is reserved until more material is studied.

The body of the youngest specimen was 7 mm. long; the form generalised; the face short; the diameter of the eye, one-half the length of the head. A narrow carapace was distinguishable in a specimen, with length of body 11 mm. In the oldest specimen the carapace was 16 x 11 mm., and had the characteristic leathery appearance and markings of the adult. The snout had also the elongated form of the adult. The feet were webbed. The diameter of the eye, though twice as great as in the youngest specimen, was only one-third the length of the head.

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1. As seen from the meson, the most striking difference between the early and late forms of the brain is the general shape. Taking as reference points the center of the geminum, the union of the myel with the oblongata, and the tip of the olfactory lobe, in the youngest embryo the figure formed is an isosceles triangle, in the succeeding stages changing to a flattened triangle by the elongation of the base. The cephalic limb of the triangle increases greatly, while the folding of the caudal part of the brain produces an actual shortening of the caudal limb of the triangle. In the adult *Amyda*, the flattening of the triangle has proceeded to an extreme. The change of form in the brain is apparently greater between the time when the external appearance of the adult is established, as in the oldest embryo, and the true adult condition, than between the oldest and youngest of the above-described embryos. This is due to the fact that after the external adult appearance is complete the cerebrum and the cerebellum both acquire their largest comparative growth.

2. At the constriction occurring in the brain-tube, between the postcommissure and the floor of the cranial flexure, the brain shows the least increase in size, as shown by different measurements upon the meson, of the embryo and adult brain. This stationary condition is probably due to the early maturing of the region.

3. The union of the olfactory lobes across the meson was not found in these turtles until the beginning of the carapace was distinguishable, and did not present the comparative extent and close connection of the adult until the oldest embryo with the adult appearance. That is, as was found with the sparrow, the union across the meson is of late occurrence and secondary importance.

4. Those parts of the cerebrum, apparently connected with olfaction, the hippocampal, progress with equal step with the olfactory lobe, and not until the oldest embryo is the fimbrial edge of the hippocamp and its union across the meson, the fornicommissure, well established. The late appearance of this commissure is consonant with great varia-

tion in different types, but this study tends to corroborate the opinion now gaining ground, that this commissure in the lower vertebrates is not a callosum.

5. That part of the cerebrum so prominent in the adult, the caudatum, or elevated portion of the striatum, is only found as a rather inconspicuous object in the oldest embryo, but the precommissure, in which fibers from the upper parts of the striatum cross, arises as the carapace begins to form.

6. In the roof of the brain the postcommissure is a well-formed landmark in the earliest of the embryos, while the commissure, bounding the opening of the epiphysis, the supracommissure, shows as a mere trace in the youngest embryo and attains a disproportionate development in the oldest. A similar culmination in growth is seen in the oldest embryo in the associated epiphysis, habenæ and the fiber tract extending from this region to the cerebrum, a fact apparently indicating that in ancestors of this group having comparatively simple brains these parts were of more importance, for in the adult turtle they are overshadowed by the later developing parts.

7. The membranous roof in all embryos is a simple unfolded membrane, clearly continuous with the paraplexuses of the cerebrum. The latter, in the early stages, are simple membranes, which show folds only when the carapace begins to develop, and become quite complex in the oldest embryo. The paraphysis, at the point of union of the diaplexus with the paraplexuses, is a widely open tube in all the stages, and becomes early convoluted.

8. The medicommissure, a feature which is found in mammals and reptiles, but not in birds, arises in this turtle only in the oldest embryo, in this being like mammals, in which it also appears late, and showing that though characteristic, it is of secondary importance.

9. In the infundibular region of the embryo are seen distinct folds and pits, which are nearly obliterated in the adult. A pair of protuberances, dorsad of the hypophysis, occurs in the younger forms, and is represented in the adult by a single

mesal notch. Dorsad of these, a mesal protuberance, lying between two commissures, is much more prominent in the younger specimens before the commissures are formed. The decision upon homologies of these protrusions of the wall with either the albicans of the higher forms or the hypoaria of fishes must be reserved, for there are details of difference with both.

10. In the turtle, all parts connected with vision are well developed. In the youngest embryo the optic recess is clearly traceable to the eye along the optic nerve, as the remains of the originally open vesicle. This remnant becomes more convoluted, the endymal cells giving an almost glandular appearance, in the stages when the carapace begins to develop. In the oldest embryo this appearance is gone, but the numerous cells of the chiasma in the adult may represent this convoluted vesicular remnant.

11. The optic geminum does not lose the form of a thin-roofed single vesicle until in the oldest embryo a mesal depression occurs, forming the paired geminums, and at the same time an extensive union across the meson by means of the geminal commissure, and a division of the cells into two layers arise. The late formation of this solid roof of the geminums is interesting in connection with the fact that in birds the roof remains a membrane.

12. In the latest embryo the cerebellum is only just beginning its growth as a great mesal feature, though considerably earlier it is apparent as a lateral organ. In the youngest embryo its appearance is like that of the *Amphibia*, having a small mesal portion. With its growth caudad it revolves, so to speak, about a fixed point, carrying the thin membranous wall before it, and thus forms the folded metaplexus of the adult. The oldest embryo shows this admirably.

13. The floor of the oblongata undergoes wonderful changes, from a comparatively thin-walled condition in the youngest embryo, through one in which series of rounded thickenings occur, these in turn becoming united, as the car-

apace develops, to form the continuous thickened floor of the oldest embryo.

From the above it is seen that partial answers to the questions mentioned are now possible.

(*a.*) The general form of the brain of the soft-shelled turtle wherein it differs markedly from the other described turtles is only acquired after the embryo has the external appearance of the adult, the great relative growth of the cerebrum and cerebellum taking place after that period. (Sec. 1, 2.)

(*b.*) The union of the olfactory lobes across the meson and the large caudal growth of the cerebellum seem to be characteristic of this group of turtles, and it was found that both are of late development. (Sec. 3, 12.)

(*c.*) The broad distinctions between the bird and reptile brain are, that the latter possesses a medicommissure and a solid roof to the geminums ; in the soft-shelled turtle both of these features arise in the late embryo.

That is, in the brain not only those features which distinguish the group of turtles, but which most evidently distinguish birds from reptiles, arise in this turtle about the time the external form is characteristic of the genera. The brain, however, lags somewhat behind the body in assuming characteristic features.

Other questions arose as to the appearance of the nidi and their relation to sulci, which cannot yet be answered conclusively.